

Claims

1. A method of producing a hollow inorganic electrode for a solid oxide fuel cell, comprising:
- 5 (a) depositing electrode material onto an electrically conductive combustible core, the electrode material including electrically conductive metal, and ionically conductive ceramic particles, wherein at least the metal is deposited by electrodeposition;
- (b) drying the core bearing the deposited electrode material; then,
- 10 (c) sintering the core bearing the deposited electrode material such that the core combusts, thereby producing a hollow electrode.
- 15
2. The method of claim 1 wherein the ceramic particles are co-deposited with the metal on the core by composite electrodeposition, thereby forming a single-layered electrode.
- 20
3. The method of claim 1 wherein the metal is first deposited on the core by metal electrodeposition to form a metal layer, then the ceramic particles are deposited onto the metal layer by one of composition electrodeposition or electrophoretic deposition, thereby producing a dual-layered electrode.
- 25
4. The method of claim 1 wherein the electrode material includes combustible particles that are deposited onto the conductive core by electrodeposition, and are combusted during sintering, thereby producing a porous electrode.
- 30
5. The method of claim 1 further comprising prior to deposition, applying masking material onto the combustible core, and after deposition, removing the masking material thereby leaving an electrode structure having openings corresponding to the masked areas, the openings being for the passage of reactant through the electrode.

6. The method of claim 1 wherein the core is of a flexible material, and further comprising after electrodepositing and before sintering, manipulating the electrode into a suitable electrode shape.

5

7. The method of claim 6 wherein the electrode is manipulated into one or a combination of shapes from the group of U-shaped, serpentine-shaped, or coiled shaped.

10

8. The method of claim 1 wherein the electrode is an anode and the metal is one in the group of nickel, copper, palladium, chromium, platinum, gold silver and/or their alloys.

15

9. The method of claim 1 further comprising after drying and before sintering, attaching a ceramic electrolyte to the outside surface of the electrode by electrophoretically depositing ceramic particles onto the electrode.

20

10. The method of claim 9 wherein the ceramic electrolyte particles are yttria-stabilized zirconia.

25

11. The method of claim 1 wherein the core is one of the group of a carbon fibre, a carbon fibre bundle, a carbon tow, or a carbon rod.

12. The method of claim 4 wherein the porosity of the electrode is controlled by one or more of controlling the duration and temperature of the sintering step, controlling the particle size, size distribution and/or surface area of the combustible particles, controlling the thickness of the electrode, or controlling the sintering atmosphere.

13. The method of claim 4 wherein the combustible particles are chosen from the group consisting of carbon, carbon black, and organic and polymeric compounds.
- 5 14. The method of claim 10 wherein the electrophoretic deposition step is repeated before sintering to form an outer electrode on the electrolyte, the ceramic material for the outer electrode being electrically and ionically conductive.
- 10 15. The method of claim 14 wherein the composition of the ceramic material of the electrolyte and outer electrode are the same, but one or more of the particle size, distribution, surface area, microstructure and porosity are different.
- 15 16. A method of producing a hollow solid oxide fuel cell comprising
- 20 (a) producing an inner electrode by depositing inner electrode material onto an electrically conductive combustible core, the inner electrode material including electrically conductive metal, and ionically conductive ceramic particles, wherein at least the metal is deposited by electrodeposition;
- 25 (b) producing a ceramic electrolyte by electrophoretically depositing a ceramic material onto the outside surface of the inner electrode;
- (c) drying the inner electrode and electrolyte;
- (d) sintering the inner electrode and electrolyte under conditions sufficient to combust the core;
- 25 (e) producing an outer electrode by attaching outer electrode material onto the outside surface of the electrolyte, the outer electrode material including electrically and ionically conductive ceramic particles and combustible particles; and,
- 30 (f) sintering the inner electrode, electrolyte, and outer electrode under conditions sufficient to combust the combustible particles,

thereby producing a hollow fuel cell structure having a porous outer electrode.

17. The method of claim 16 further comprising between steps (a) and (b),
5 sintering the core-bearing the inner electrode under conditions sufficient to
combust the core.

18. A method of producing a hollow inorganic membrane, comprising:

- 10 (a) electrodepositing an inorganic material that includes electrically
conductive metal onto an electrically conductive combustible core;
(b) drying the core bearing the deposited inorganic material; then,
(c) sintering the core bearing the deposited inorganic material such
that the core combusts, thereby producing a hollow inorganic
metal-containing membrane.

15 19. The method of claim 18 wherein the material also includes ceramic
particles that are co-deposited with the metal on the core by
electrodeposition, thereby producing a hollow inorganic cermet
membrane.

20 20. The method of claim 18 wherein the material also includes combustible
particles, and sintering the membrane also combusts the combustible
particles, thereby producing a hollow porous inorganic membrane.

25 21. The method of claim 18 further comprising after electrodepositing and
before sintering, electrophoretically depositing ceramic particles onto the
metal-containing membrane, thereby forming a multi-membrane hollow
structure having an inner metal-containing membrane, and an outer
ceramic membrane.

22. The method of claim 21 wherein combustible particles are electrophoretically co-deposited with the ceramic particles onto the metal-containing membrane, and sintering the multi-membrane structure also combusts the electrophoretically deposited combustible particles, thereby producing a multi-membrane structure having a porous inner and outer membrane.
- 5
23. The method of claim 18 wherein the core is of a flexible material, and further comprising after electrodepositing and before sintering, manipulating the membrane into a desired shape.
- 10
24. The method of claim 23 wherein the electrode is manipulated into one or a combination of shapes from the group of U-shaped, serpentine-shaped, or coiled shaped.
- 15
25. The method of claim 18 wherein the metal is one in the group of nickel, copper, palladium, chromium, platinum, gold silver and/or their alloys.
- 20
26. The method of claim 18 wherein the ceramic particles are yittria-stabilized zirconia.
27. The method of claim 18 wherein the core is one of the group of a carbon fibre, a carbon fibre bundle, a carbon tow, or a carbon rod.
- 25
28. The method of claim 20 wherein the porosity of each membrane is controlled by one or more of controlling the duration and temperature of the sintering step, controlling the sintering atmosphere, controlling the particle size, size distribution and/or surface area of the combustible particles, or controlling the thickness of the membrane.
- 30

29.The method of claim 20 wherein the combustible particles are chosen from the group consisting of carbon, carbon black, and organic and polymeric compounds.

5 30.A hollow solid oxide fuel cell comprising:

- (a) an electrodeposition-formed inner electrode having a composition that includes an electrically conductive metal material and an ionically conductive ceramic material;
- (b) a non-porous electrolyte electrophoretically deposited on the inner electrode and having a composition that includes a ionically conductive ceramic material; and,
- (c) an outer electrode attached to the outer surface of the electrolyte and having a composition that includes an electrically an ionically conductive ceramic material.

15 31.The fuel cell of claim 30 wherein the outer electrode is deposited on the electrolyte by electrophoretic deposition.

20 32.The fuel cell of claim 30 wherein the outer electrode is attached to the electrolyte by dip coating the electrolyte and inner electrode in a ceramic particulate bath.

25 33.The fuel cell of claim 30 having one or a combination of a U-shape, serpentine shape, or helical shape.

34.The fuel cell of claim 30 wherein the ceramic material for the outer electrode is different or has different characteristics than the electrolyte.

30 35.The fuel cell of claim 34 wherein the ceramic material of the electrolyte and outer electrode are the same, but one or more the ceramic particle size, distribution, surface area, microstructure or porosity is different.

36.The fuel cell of claim 30 wherein the metal material of the inner electrode is one in the group of nickel, copper, palladium, chromium, platinum, gold silver and/or their alloys.

5

37.The fuel cell of claim 30 wherein the ceramic material of the electrolyte is yittria-stabilized zirconia.

10 38.The fuel cell of claim 30 wherein the ceramic material of the outer

electrode is lanthanum strontium manganate.

15 39.A hollow inorganic multi-layered membrane apparatus comprising:

- (a) a hollow electrodeposition-formed inner membrane having a composition that includes a metal material; and,
- (b) an outer membrane electrophoretically deposited on the inner membrane and having a composition that includes a ceramic material.

20 40.The apparatus of claim 33 having one or a combination of a U-shape, serpentine shape, or helical shape.

25 41.The fuel cell of claim 36 wherein the metal material of the inner membrane is one in the group of nickel, copper, palladium, chromium, platinum, gold silver and/or their alloys.

42.The fuel cell of claim 27 wherein the ceramic material of the outer membrane is yittria-stabilized zirconia.

30